Nuffield Foundation

Towards universal participation in post-16 mathematics: lessons from high-performing countries

Technical report

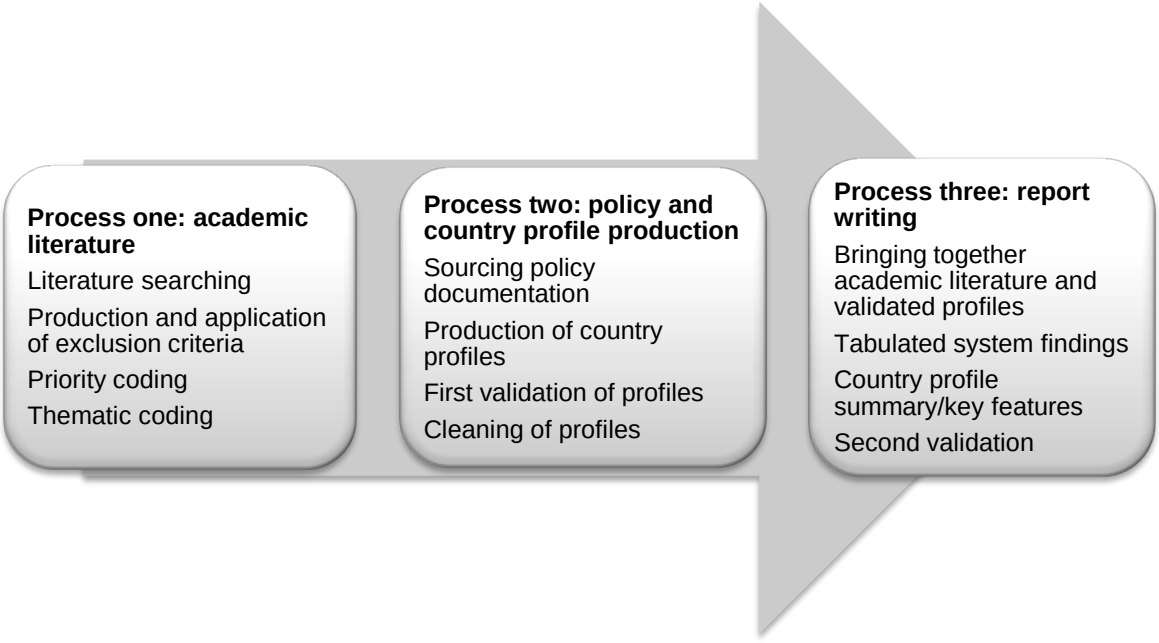
Contents

Introduction

This technical report details the methods used in conducting the study *Towards universal participation in post-16 mathematics: lessons from high-performing countries.* The study is a follow-up to *Is the UK an outlier? An international comparison of upper secondary mathematics education*[1]. This earlier report was based on data collected for 24 different countries[2]. As a result, we already hold information about their policies on participation in upper secondary mathematics and data on their levels of participation. However, we have a limited amount of information about the factors that mediate the impact of these policies and result in higher or lower levels of participation. We also have limited information about the content and level of upper secondary mathematics in these countries.

To develop a fuller picture of what encouraging participation in upper secondary mathematics might mean in each of these countries, further information is needed. This document sets out the methods used to obtain this information. In response to our research questions, we used a combination of the methods used in the earlier *Outlier* study and the *Values and variables*[3] study to draw together the academic/research literature and the 'grey' or policy-oriented literature. This document also contains a description of how the participation rates in the main report were calculated.

The work was carried out between April and October 2012. The methodology consists of two distinct routes – academic and policy literature – which were conducted linearly and then brought together in the third process of writing of this report. The three processes and their stages, outlined in the diagram below, are discussed in detail in this report.



[1] Hodgen, J., Pepper, D., Sturman, L., & Ruddock, G. (2010). *Is the UK an outlier? An international comparison of upper secondary mathematics education*. London: Nuffield Foundation.

[2] We use the term 'country' to describe the different education systems included in the study, although for Germany and the USA, we have only looked in detail at one state or land, and Hong Kong is a special administrative region of China rather than a country. We have done this so that the terminology is consistent with the previous study and because we needed a simple description that could be used across what is actually a group of different legal, political and social entities.

[3] Askew, M., Hodgen, J., Hossain, S., & Bretscher, N. (2010). *Values and variables: mathematics education in high-performing countries*. London: Nuffield Foundation.

Literature definitions

Literature was sourced and used under two categories: academic and policy. Academic literature referred to material by and for an academic and wider audience, including:

- Journal articles (refereed and non-refereed)
- Books and book chapters
- Presentations and conference papers
- Theses

Policy literature relates to material produced by and for policy groups and departments, public information (including websites) and grey literature, including:

- Policy documents (e.g. reports by education departments and other government bodies)
- Curricular documents
- Published statistical data
- Discussion papers
- Public information publications

Process one: academic literature

Table 1 provides a summary of the academic literature sourced and included within this study. The stages and relevant criteria are discussed in the following sections.

Table 1: Academic literature overview				
Initial search	**Following all exclusion and cleaning stages**	**Relevant literature**	**Partially relevant literature**	**Relevant and partially relevant literature for inclusion in study**
1,243,608	743	173	141	314

At all stages, the methods described below were tested with one country, discussed as a research team and amended as necessary.

Stage one: literature searching

Initially the previous report and the research questions of the current report were reviewed in drawing up a list of search terms. These search terms were tested and reviewed as a research team in order to produce a final search term list to be applied to each country. Taking account of country-specific terminology, for instance for upper-secondary level education, flexibility was built into the search term list and adjusted following input from an expert of the country and/or consultation with country documentation. Wildcards were used

to account for the use of terms such as ‘math’, ‘maths’ and ‘mathematics’. A matrix was produced for recording search outcomes, and the actual search terms used were included within this to maintain an audit trail.

The search term strings fell into three categories: place of mathematics, general background, and issues related to recruitment and participation. These are set out in **Table 2**.

Table 2: Search strings used in academic literature searching	
Category	**Search String**
Place of mathematics within country	[math*] AND [<country >] AND [utility OR value OR status]
General background on secondary mathematics within country	[math*] AND [education] AND [<country >] AND [secondary OR "high school" OR <country specific terminology>] AND [curriculum]
	[math*] AND [education] AND [<country >] AND [secondary OR "high school" OR <country specific terminology>] AND [attainment]
	[math*] AND [education] AND [<country >] AND [secondary OR "high school" OR <country specific terminology>] AND [attitude OR affect OR identity]
Recruitment and participation in upper secondary mathematics	[math*] AND [education] AND [<country >] AND ["upper secondary" or "post 16" or "further education" or "A level" or "AS level" OR <country specific terminology>] AND [recruitment OR "entry requirement"]
	[math*] AND [education] AND [<country >] AND ["upper secondary" or "post 16" or "further education" or "A level" or "AS level" OR <country specific terminology>] AND [participation]
	[math*] AND [education] AND [<country >] AND ["upper secondary" or "post 16" or "further education" or "A level" or "AS level" OR <country specific terminology>] AND [expenditure]
	[math*] AND [education] AND [<country >] AND ["upper secondary" or "post 16" or "further education" or "A level" or "AS level" OR <country specific terminology>] AND [choice OR option]
	[math*] AND [education] AND [<country >] AND ["upper secondary" or "post 16" or "further education" or "A level" or "AS level" OR <country specific terminology>] AND [course OR content]
	[math*] AND [education] AND [<country >] AND ["upper secondary" or "post 16" or "further education" or "A level" or "AS level" OR <country specific terminology>] AND [continuation OR drop-out OR attrition]
	[math*] AND [education] AND [<country >] AND ["upper secondary" or "post 16" or "further education" or "A level" or "AS level" OR <country specific terminology>] AND [pedagogy OR "teaching methods"]
	[math*] AND [education] AND [<country >] AND ["upper secondary" or "post 16" or "further education" or "A level" or "AS level" OR <country specific terminology>] AND [materials OR "text books"]
	[math*] AND [education] AND [<country >] AND ["upper secondary" or "post 16" or "further education" or "A level" or "AS level" OR <country specific terminology>] AND [assessment OR qualification*]

A list of search sources and databases was produced based on previously used sources, awareness of the area and recommendations from others. The sources employed by systematic reviewers, such as the Evidence for Policy and Practice Information and Co-ordinating Centre[4], were also consulted in order to ensure a comprehensive database and source list. The same databases were searched for each country. Particular websites allowed combined database searches while others were conducted on an individual basis. **Table 3** sets out the databases and sources used within the literature search. Other databases were initially included, but were removed later when found not to produce new literature.

Table 3: Databases and sources used in academic literature searching	
Database Group	**Individual Databases and Literature Search Sources**
CSA Illumina	Applied Social Sciences Index and Abstracts (ASSIA) - http://csaweb105v.csa.com/ids70/quick_search.php?SID=nusq0fpem0fnfq95q1d8fjsg57
	ERIC - http://search.proquest.com/professional/eric/advanced?accountid=11862
	International Bibliography of the Social Sciences (IBSS) - http://csaweb105v.csa.com/ids70/advanced_search.php?SID=0u3g0qvhthk84mm27qeuk4a4f1&tab_collection_id=0
	Sociological Abstracts - http://csaweb106v.csa.com/ids70/advanced_search.php?SID=54febfukqqjdjr9b466suvu3n5&tab_collection_id=0
Proquest	Australian Education Index - http://search.proquest.com/professional/australianeducationindex/advanced?accountid=11862
	British Education Index (EducationLine) - http://search.proquest.com/professional/britisheducationindex/advanced?accountid=11862
Web of Knowledge	Social Science Citation Index / Web of Knowledge - http://apps.webofknowledge.com/WOS_GeneralSearch_input.do?highlighted_tab=WOS&product=WOS&last_prod=WOS&search_mode=GeneralSearch&SID=W2eIhO5pPjgpOpOF7e1
	Conference Proceedings Citation Index – Social Science & Humanities (CPCI – SSH)
Individual Databases	Google Scholar - http://scholar.google.co.uk/advanced_scholar_search?hl=en&as_sdt=0,5
	IngentaConnect - http://www.ingentaconnect.com/search/advanced
	MathEduc - http://www.zentralblatt-math.org/matheduc/
	PsycINFO (2002 onwards) - http://ovidsp.uk.ovid.com/sp-3.5.1a/ovidweb.cgi?&S=FAGIPDIGCAHFKHNMFNALFCEGFBJOAA00&New+Database=Single%7c13

[4] EPPI-Centre. (2006). *EPPI-Centre methods for conducting systematic reviews.* London: EPPI-Centre, Social Science Research Unit, Institute of Education, University of London.

A matrix was produced in Excel mapping each search string with each database and literature source. This allowed a record to be kept of the literature sources through each combination for each country.

Since electronic databases are not completely comprehensive and tend to include more academic journal articles, supplementary manual searches were carried out in the King's library, on the web, by asking colleagues and on advice from the national experts.

Following initial searching, over 1.2 million documents were produced, much of which was inappropriate for a study such as this. First level exclusion criteria were drawn up to be applied across the literature sourced. These were designed to be applied to document titles, by sight, removing obviously unsuitable literature. Where there was any doubt, the literature was retained at this stage. First level exclusion criteria fell under three categories: off-topic, date and language, duplicates. These are set out in **Table 4**. An example of an article that was excluded at this stage as this was obviously outside of the topic area we were interested in was:

> Chib, A. (2011). Midwives with mobiles: A dialectical perspective on gender arising from technology introduction in rural Indonesia. *New Media & Society*, 13(3), 486-501.

Table 4: First level exclusion criteria used in academic literature searching

Off-topic	Topic	Clearly not related to project in any way
	Subject area	Generally only include mathematics but consider background information available in literature with other subject foci
	Schooling level	Include all secondary. Primary and tertiary may include important background – only reject if obviously irrelevant
	Country	If applicable file to other Endnote country file or general Endnote file
Date and language	Language	Not in English (except German literature)
	Date	Only reject at this stage if clearly out of date and therefore irrelevant, possibly where later report is available. If any doubt, include at this stage
Duplicates		Obvious duplicates can be ignored at this stage

Results from Google Scholar searches were treated differently due to the vast quantities of literature produced. These were sorted by relevance (according to Google criteria) and only the first 250 documents assessed unless less than 250 documents were forthcoming. This cut-off point was based on testing the results produced and assessing the point at which little further relevant new literature was forthcoming.

The language exclusion criteria were not applied to the German literature search and support was sought from a native speaker in accessing and translating this literature.

Following first level exclusion, documents retained were recorded in the literature search matrix, and the references imported (automatically where possible) into Endnote where they

were grouped by the country they referred to. Full references were imported including abstracts. The Endnote file was cleaned at this stage to remove any duplicates or any documents that had fallen through the first level exclusion application.

Stage two: production of level two exclusion criteria

At this stage it was necessary to further exclude items and clean the database. The first level exclusion model was extended and made more rigorous to produce the second level exclusion model. Extending the first level model was purposeful in maintaining continuity and ensuring documents that may have fallen through the first level were picked up at this stage.

The second level exclusion model was applied to all literature in the country Endnote files and these were reduced accordingly. The date criteria were applied to ensure the literature reflected current policies. However, where important literature related to thematic areas and not to specific countries was sourced, this was judged on an individual basis and some pre-2000 documents retained. For example, an older article examining concepts within attitude but unrelated to current policies was retained:

> Marsh, H., Byrne, B., & Shavelson, R. (1988). A multifaceted academic self-concept: Its hierarchical structure and its relation to academic achievement. *Journal of Educational Psychology*, 80(3), 366-380.

Table 5: Second level exclusion criteria used in academic literature searching

Off-topic (apply more stringently)	Subject area	Not related to mathematics or useful as background
	Thematic area	Not related to issues of recruitment and participation
	Schooling level	Not related to secondary mathematics or useful as background – but include HE/other pathways on expectations
	Country	Not applicable to country under consideration
Language and date	Language	Main document not available in English (except for case of Germany)
	Date	Decision made to exclude on date as no longer relevant or more up-to-date literature available - 2000
Rigour	Small sample size	Sample size too small for reliable conclusions at a country level
	High drop-out rate	Apparently high drop-out rate from study
	Inadequate description of method	Impossible to fully ascertain method used from description given
Literature quality	Full text unavailable	Note any literature that appears important but is unavailable – but do not exclude
	Theoretical commentary pieces	Discuss individual cases

Following all exclusion stages and cleaning, 743 documents remained in the Endnote database.

Stage three: priority coding

At this stage, our aim was to reduce the quantity of literature substantially and to begin to identify the key documents that would form the basis of our review. A priority coding scheme, ranking the literature 1 – 3 or F (to be followed up for instance where it was not possible to make a judgement from the abstract alone) was produced (see **Table 6**).

Table 6: Priority coding scheme used in academic literature searching		
Priority:	Relevant – full publication important to review	**1**
	Partially relevant – aspects of publication may be important to review	**2**
	Exclude	**3**
	Follow-up (give reason)	**F**

As a research team, we priority-coded the literature filed for each country individually, before discussing the priority codes assigned in order to ensure inter-coder reliability. Where there was disagreement in the priority code to assign a particular document, this was discussed, checked against our research questions, and agreement reached about the most appropriate priority code.

The priority codes were attached to the individual literature through the addition of a priority coding category to the Endnote file. Literature coded as 1, 2, or F was then extracted into a separate priority literature Endnote Group, again subdivided by country. The documents coded as relevant or partially relevant (priority 1 and priority 2) were sourced and attached to the Endnote file for easy reference.

Once full-texts had been secured, the limited literature that had been initially priority-coded F (follow-up) was reassessed and coded 1-3. Any literature coded 3 at this stage was removed from the priority literature Endnote Group. The Endnote file was again cleaned and a final table detailing the quantity of literature produced for each country at each stage was produced (see **Table 7**). In total, 314 documents coded as relevant (173 documents) or partially relevant (141 documents) remained.

Table 7: Total literature sourced in each stage of academic literature searching				
Country	**Initial search**	**Following all exclusion and cleaning stages**	**Relevant literature (priority 1)**	**Partially relevant literature (priority 2)**
General international, comparative and background literature	224,695	37	26	18
England	202,318	166	46	39
Germany (general)	122,765	87	12	12
Germany (Rhineland-Palatinate)	360	14	3	1
Hong Kong	34,401	42	7	10
New Zealand	73,881	86	20	20
Scotland	76,433	31	11	6
Singapore	137,798	145	17	15
US (general)	218,169	55	20	13
US (Massachusetts)	152,788	80	11	7
Total	**1,243,608**[5]	**743**	**173**	**141**

Stage four: Thematic coding

Having prioritised and reduced the literature considerably, we then coded the remaining priority literature thematically. A coding scheme, divided into ten areas representing our interests and research questions, was produced, with the areas subdivided as necessary. The ten areas match the profile design used with the policy literature (described in **process two**) in order to give coherence across both sets of literature. The thematic coding scheme is shown in **Table 8**.

Table 8: Thematic coding applied to the results of academic literature searching			
Thematic Coding		**Endnote Code**	**Descriptive Code**
General	General country background information	**0**	**00**
Optional and compulsory upper secondary mathematics options	Upper secondary – compulsory/optional and structure	**1**	**10**
	Upper secondary mathematics – compulsory courses		**11**
	Upper secondary mathematics – optional courses		**12**

[5] This figure will include double counting as some literature was sourced for multiple countries.

Table 8: Thematic coding applied to the results of academic literature searching			
Thematic Coding		**Endnote Code**	**Descriptive Code**
Participation levels	Current participation levels in different options	**2**	**20**
	Gender differences in participation		**21**
	Change over time		**22**
Content and level of upper secondary mathematics	Structure and content of the mathematics options	**3**	**30**
	Teacher training (upper-secondary-specific)		**31**
Upper secondary summative assessment	Types of summative assessment	**4**	**40**
	Alternative assessments		**41**
Secondary mathematics learning outcomes	Expectations, attitudes and attainment in lower secondary mathematics	**5**	**50**
	Expectations, attitudes and attainment in upper secondary mathematics		**51**
Upper secondary vocational education	Structure and content of vocational courses	**6**	**60**
	Inclusion of mathematics (and level) in vocational education		**61**
	Status of vocational courses		**62**
	Participation levels in vocational courses		**63**
Drivers in the uptake of mathematics	Official and unofficial criteria for acceptance onto upper secondary mathematics options	**7**	**70**
	Careers and subject option information and guidance, including targeted recruitment		**71**
	Criteria for HE mathematics and views of HE and employers		**72**
Transition	Policy and practice in the transition to upper secondary mathematics	**8**	**80**
Recruitment and retention	Factors attributable to recruitment and retention in upper secondary mathematics	**9**	**90**

Each item of literature was coded using the thematic coding scheme. Again, inter-coder reliability checks on the application of the coding scheme were made. As with the priority coding, separate categories were added to the Endnote File to allow the thematic coding results to be recorded here. The Endnote coding numbers were selected to allow for easy searching and retrieval of thematic literature groups both within and between countries. The predominant code applied to each document is shown in **Table 9**. 111 of the 314 relevant and partially relevant (35%) addressed multiple questions and this was multiple-coded as required. The multiple coding applied to the documents is shown in **Table 10**. The use of the coded literature is discussed under **Process three: report production**.

Table 9: Most prominent code applied to all academic literature by country and thematic totals																							
Literature coded by country (most prominent category coding)																							
Thematic Coding	**General Lit.**		**England**		**Germany (general)**		**Germany (R-P)**		**Hong Kong**		**New Zealand**		**Scotland**		**Singapore**		**US (general)**		**US (MA)**		**Totals**		
Priority	**1**[6]	**2**[7]	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**All**
General	10	6	5	8	6	6	2	1	3	4	1	4	4	1	6	2	9	3	2	2	48	37	85
Optional and compulsory upper secondary mathematics options	0	2	5	2	0	0	0	0	0	0	1	0	2	0	0	1	0	2	1	0	9	7	16
Participation levels	0	1	10	6	0	2	0	0	0	0	0	3	1	1	0	1	2	1	0	0	13	15	28
Content and level of upper secondary mathematics	3	1	2	3	1	2	0	0	2	3	5	1	0	0	5	3	0	0	0	0	18	13	31
Upper secondary summative assessment	3	0	1	1	1	0	1	0	0	1	4	4	1	0	2	1	0	1	3	1	16	9	25
Secondary mathematics learning outcomes	9	3	6	4	1	1	0	0	0	2	3	6	0	2	4	6	4	2	3	2	30	28	58
Upper secondary vocational education	0	0	5	1	3	0	0	0	0	0	0	0	2	0	0	1	0	0	0	1	10	3	13
Drivers in the uptake of mathematics	0	1	4	10	0	0	0	0	2	0	6	2	0	0	0	0	2	3	2	0	16	16	32
Transition	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	2
Recruitment and retention	1	4	6	4	0	1	0	0	0	0	0	0	1	2	0	0	3	1	0	1	11	13	24
Totals	**26**	**18**	**46**	**39**	**12**	**12**	**3**	**1**	**7**	**10**	**20**	**20**	**11**	**6**	**17**	**15**	**20**	**13**	**11**	**7**	**173**	**141**	**314**

[6] Relevant literature
[7] Partially relevant literature

Table 10: All thematic coding applied to academic literature - includes multiple coding																						
Literature coded by country (including multiple coding)																						
Thematic Coding	**General Lit.**		**England**		**Germany (general)**		**Germany (R-P)**		**Hong Kong**		**New Zealand**		**Scotland**		**Singapore**		**US (general)**		**US (MA)**		**Totals**		
Priority	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**All**
General	10	6	11	10	6	6	2	1	7	8	2	4	5	2	9	2	10	4	2	2	64	45	109
Optional and compulsory upper secondary mathematics options	1	2	9	2	0	1	1	0	4	5	2	0	4	0	2	1	0	2	2	0	25	13	38
Participation levels	0	1	15	6	0	2	0	0	3	0	0	3	1	1	0	2	5	4	1	0	25	19	44
Content and level of upper secondary mathematics	5	1	4	3	3	3	0	0	5	4	5	1	1	0	6	3	2	0	1	0	32	15	47
Upper secondary summative assessment	3	0	1	1	1	1	1	0	0	2	6	5	1	0	4	1	3	1	4	2	24	13	37
Secondary mathematics learning outcomes	11	4	10	5	2	2	0	0	3	6	5	7	3	2	5	6	6	2	3	2	48	36	84
Upper secondary vocational education	0	0	9	2	3	0	0	0	1	0	0	0	3	0	0	1	0	1	0	1	16	5	21
Drivers in the uptake of mathematics	0	2	10	12	1	2	0	0	4	1	6	2	1	0	1	0	4	4	3	0	30	23	53
Transition	0	0	4	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	5	2	7
Recruitment and retention	1	4	11	8	1	2	0	0	6	6	2	0	1	2	0	0	4	1	1	1	27	24	51
Totals	**31**	**20**	**84**	**50**	**17**	**19**	**4**	**1**	**33**	**32**	**28**	**22**	**20**	**7**	**27**	**16**	**35**	**20**	**17**	**8**	**296**	**195**	**491**

Process two: policy and country profile production

The policy search was combined with the production of extended profiles for each of the countries we were interested in. This method was used successfully in the previous report[8] and one researcher on this project has further previous experience of using this method[9]. The combined process is detailed below.

Stage one: sourcing policy documentation

Combining the country profile format used in the previous report with our research questions in this report, we produced a template highlighting the key information we were interested in collating for each country and the questions we had about their educational systems. This information was then sourced through a variety of literature types such as:

- Policy documents (e.g. reports by education departments and other government bodies)
- Curricular documents
- Published statistical data
- Discussion papers
- Public information publications

The URLs listed in the previous country profiles were extracted and updated as necessary to repair missing or broken links and to update to more recent publications of documents where applicable. Information from these links was then inserted into the new template. Links from these documents and webpages were followed up systematically to add to our pool of data.

A decision about the applicability of a source was made as each was located; this was based on applying the exclusion criteria used with the academic literature and making an informed judgement about the source based on where it was from and the extent to which it provided information we were interested in. All sources used were referenced (with URLs given where available) within the country profile. The documents and links were recorded in a separate policy group (again separated by country) within the Endnote file constructed for the academic literature. Copies of webpages as they existed on the date of access were included. Policy documentation became available from country experts as we raised questions and referenced within the appropriate section of the country profile, so this material was not separately thematically coded.

Further data was then sourced through systematic online searches for each country based on the questions within the template. Searches were made of publications produced by departments and research groups in the countries we were interested in, similar to the following examples from the English context:

- Department for Education

[8] Hodgen, J., Pepper, D., Sturman, L., & Ruddock, G. (2010). *Is the UK an outlier? An international comparison of upper secondary mathematics education*. London: Nuffield Foundation.
[9] Gordon, J., Halasz, G., Krawczyk, M., Leney, T., Michel, A., Pepper, D., Putkiewicz, E., Wiśniewski, J. (2009). *Key competences in Europe: opening doors for lifelong learners across the school curriculum and teacher education*. Warsaw: CASE Network Reports.
Leney, T., Gordon, J., & Adam, S. (2008). *The shift to learning outcomes: policies and practices across Europe*. Thessaloniki: European Centre for the Development of Vocational Training.

- National Foundation for Educational Research (NFER)
- Office for National Statistics

Many such sites provided links to other sites and these were systematically followed up. In addition, INCA, Eurydice and the 2007 TIMSS Encyclopaedia were consulted and again any related links followed up.

The quantities and types of information available for each country varied considerably, with extensive documentation available for England. **Table 11** details the total number of sources drawn on for each (including websites and policy documents).

Table 11: Policy documentation sourced and included in each profile

Country	Total documentation
England	114
Germany (Rhineland-Palatinate)	47
Hong Kong	18
New Zealand	52
Scotland	22
Singapore	32
US (Massachusetts)	55
Total policy documentation	340

Stage two: production of country profiles

Following sourcing of the documentation as set out above, relevant information was extracted and input into the country profiles. Where statistical data was included, for instance on participation rates, it was necessary with some of the information to make calculations and/or estimates based on the information available. Where this was the case, this was noted as a footnote.

All questions within the profile were answered as fully as possible with the data available. Questions we were unable to answer at this stage were highlighted. We also identified specific questions we had about each country which arose from our reading of the academic and policy literature or from our analysis of the available statistical data. We were particularly aware that countries collated and recorded statistical information differently, and included questions in relation to our understanding of this data.

Stage three: first validation of profiles

Having completed the profiles as fully as possible, highlighted gaps and identified country-specific questions, the profiles were sent out to experts in each country for validation. The validators were asked to:

- Check the information we had included for understanding and any inaccuracies

- Provide answers to the highlighted gaps, supported with links to websites and documentation
- Provide answers to our specific questions, supported with links to websites and documentation
- Give links to further documentation, particularly documentation not available to the general public, that supported our understanding of the country

Validators returned the profiles with their additional information which were checked and clarified as necessary.

Stage four: cleaning of profiles

The information received from the validators was incorporated into an updated version of each country profile. Further documentation and URLs provided were added to the Endnote file. Where statistical data was provided, work was done on this to extract the information we were interested in and added to the profile. Where necessary, clarification or further information was sought from the country experts. The revised profiles were then revalidated by the validators.

At the end of this process, a set of country profiles addressing our key research questions was available.

Process three: report production

At this stage, we had thematically coded academic literature and a cleaned validated profile for each country. This section details how these were used in writing this report.

Stage one: bringing together academic literature and validated profiles

In writing the report, information was extracted from both the academic (literature database) and policy (profile) resources we had developed. The report structure was designed to address our research questions and the factors emerging from the literature and profiles, ensuring clarity in presentation. For each question and country:

- key academic texts were identified (searches of Endnote file using thematic coding)
- texts were read as a research team and relevant information identified
- discrepancies across texts were discussed (taking account of this not being a systematic literature review)
- information was extracted from the profile

These sources of information were combined in writing the main text of the report.

It should be noted that although our academic literature search produced 173 publications categorised as relevant, these do not all appear in this report. We found considerable overlap in the content of this literature and hence selected the most pertinent and up-to-date publications. Further, although the literature addressed issues of background interest to us –

such as the content of upper secondary mathematics – there were few research studies specifically examining the relationship between this and levels of participation as shown in tables 9 and 10. Further limitations of the literature are discussed within the main report.

Stage two: tabulated country findings

To ensure consistency between the previous report and this report and to make the report findings easily accessible, country information was tabulated in relation to our research interests.

The same tabulation structure and approach as used in the previous report were employed, although these were adapted as necessary for the requirements of this report.

Stage three: country profile summaries and key features

Within the process of producing this report, we identified key features of the particular countries which marked them out as different or may have explained a particular outcome. We were keen to highlight these issues as they may form the basis of discussion or policy recommendations. As such, key country profile facts were included for each country within the report.

Stage four: second validation

Having written the report addressing our questions with respect to each country, this information was resent to the country experts to ensure the information had been used and understood correctly.

The review was then edited and policy recommendations added.

Participation rates in upper secondary mathematics – calculation notes

These notes describe how we calculated the participation rates in the report.

England

Some mathematics: Our estimate of 20%-26% for the participation rate in some mathematics has changed from our previous report (Hodgen et al., 2010) to include GCSE retakes in the upper limit. It is difficult to calculate a valid and reliable estimate of participation rates in mathematics in England. In our judgement, and in order to provide an estimate that is valid for our purpose of comparing participation between countries, the best solution is to follow the same procedure as in our previous report in which we estimated participation in basic mathematics on the basis of FSMQs, Functional Skills and Key Skills as slightly under 7%. Hence, adding this to the proportion studying advanced mathematics, the lower limit of total participation in at least basic mathematics is slightly under 20%. In 2009, 8% of those entered for GCSE mathematics were aged 17, 18 or 19: 35,777 aged 17

(5.2%), 13,042 aged 18 (1.9%) and 5,488 aged 19 (0.8%)[10]. Assuming that those entered at age 18 and 19 have already retaken GCSE at age 17, GCSE re-sits constitutes approximately 6% of the Education, Employment and Training cohort and 5% of the age cohort.

An important issue here is that the upper secondary education system in England does not appear to be particularly successful in addressing the mathematical attainment of those studying basic mathematics. For example, only an additional 3% of the cohort have gained a GCSE grade C or equivalent by age 19 (Wolf, 2011). (See England country profile for a more detailed explanation of our calculations).

Advanced mathematics: Our estimate that 13% of the education, employment and training cohort take advanced mathematics is unchanged from our previous report (Hodgen, et al., 2010). At Level 3, or advanced mathematics in Upper Secondary, qualifications are dominated by A-level qualifications, although there are small numbers of alternative qualifications, such as IB or Cambridge Pre-U. Additionally, some advanced mathematics is embedded within vocational courses, particularly engineering, although our interpretation of the FE STEM data project suggests that these account for a very small number of students (Royal Academy of Engineering, 2011). Hence, in calculating these estimates, we focus on AS and A2 qualifications. (See England country profile for more detail on the calculations.)

Mathematics in vocational education: The Royal Academy of Engineering's (2011) analysis of FE and Skill sector STEM data suggests that there a relatively large number of qualifications with mathematics, mathematics-related or numeracy components taken by students aged 16-19. However, the data available are not of a high quality. The data records all enrolments, completions and achievements, but does not distinguish multiple achievements by individual students (and there is likely to be a considerable amount of double-counting). Aside from stand-alone courses such as Functional Skills, Key Skills, GCSE or A-level, many of these courses are available as embedded modules within larger vocational courses and it is not clear whether the mathematics, mathematics-related or numeracy module is actually taken. Our judgement of the data suggests that many apparently mathematics-related modules may actually involve very little mathematical content.

Moreover, some students who have already achieved a GCSE grade C or equivalent may be exempted from the mathematics component. Indeed, more than half of these qualifications are at Level 1 or below and the FE STEM data report concludes that the evidence suggests that "some learners may be taking qualifications below the level they have already achieved whilst others are taking no mathematics or numeracy beyond 16" (Royal Academy of Engineering, 2011, p. 37). A further issue is that the number of qualifications fluctuates very significantly from year to year and the FE STEM data project concludes that this provision is particularly responsive to institutional factors other than student demand or need (e.g. funding, targets or league tables). Such variation increases the likelihood of students taking inappropriate qualifications.

[10] Gill, T. (2010). How old are GCSE candidates? Statistics Report Series No. 20. Cambridge: Research Division Statistics Group Assessment Research and Development, Cambridge Assessment.

Germany (Rhineland-Palatinate)

Some mathematics: The estimate of greater than 90% participation in at least basic mathematics is unchanged from our previous report.

Advanced mathematics: The estimated range of between 8% and 14% participation in advanced mathematics is unchanged from our previous report. Rhineland-Palatinate is considered by country experts to have a higher level of participation than average for Germany.

Mathematics in vocational education: In Germany, approximately 80% of upper secondary students are in vocational routes. All students in technical vocational and 90% of other vocational students are required to take mathematics. Some students of vocational education, such as engineering, also study advanced mathematics, although, as we found for our previous report, detailed participation data is not available for mathematics in vocational routes. Hence, the estimate of between 2.5% and 10% of students in vocational also studying advanced mathematics is unchanged from our previous report.

Hong Kong

Some mathematics: We have significantly revised our estimate of participation in at least basic mathematics upwards as a result of better information and to take account of changes to the educational system[11]. Recent reforms to upper secondary education have incorporated previously vocational or applied pathways into general upper secondary education. Mathematics is now compulsory in general education. In 2012, at least 95% of the age cohort participated in some mathematics in upper secondary education.

Advanced mathematics: We have revised our estimate of participation in advanced mathematics upwards. Approximately 22-23% of the HKDSE upper secondary cohort study advanced mathematics, which is over 20% of the upper secondary age cohort. This places Hong Kong in the category of medium participation. While we now have better data on participation, it is possible that there may have been some increases in advanced participation as a result of the recent reforms.

Mathematics in vocational education: Negligible. Almost all of upper secondary education is now incorporated within general education as a result of recent reforms.

New Zealand

Some mathematics: The participation rates in 2011 in mathematics at NCEA Level 1 or above are 96%, 84% and 65% for Year 11, Year 12 and Year 13 respectively. These are equivalent to 96% of 15/16-year-olds in education, employment or training, 71% of those 16/17-year-olds and 44% of those 17/18-year-olds. Using the Year 12 figure, most students in upper secondary study some mathematics, although this figure drops to below 50% for Year 13.

Advanced mathematics: Participation in advanced mathematics (NCEA Level 2/3 mathematics with calculus or mathematics with statistics) in 2009 is estimated to have been:

[11] The reforms have not made a huge difference to the participation rates. Participation in at least some mathematics appears to have been high previously. However, the information available on previously vocational routes is substantially better.

- 66% of all Year 12 equivalent students (16/17-year-olds) in education, employment or training (mostly at NCEA Level 2)
- 40% of all Year 13 students (17/18-year-olds) in education, employment or training (mostly at NCEA Level 3)

Not all of these students are taking a full subject (the 14 Level 3 credits required for a subject to count as a full subject for entrance to higher education). Around 13% of the Y13 cohort completes credits in both mathematics with calculus and mathematics with statistics.

Mathematics in vocational education: Negligible. Almost all of upper secondary education is in general, or school, education.

Scotland

Some mathematics: 67% of the S5 (Year 12 equivalent) and 39% of the S6 (Year 13 equivalent) cohorts in general education take at least some mathematics. This is equivalent to 48% and 21% of the education, employment and training (EET) cohorts, respectively. Many students enter higher education after S5 and so we use the S5 figure for the estimate included in the table.

Advanced mathematics: We estimate that participation in Scottish Higher Mathematics, as measured by examination passes, is likely to be around 27% of the EET cohort. We note that Higher Mathematics is broadly equivalent to the pure elements of AS level Mathematics. In addition, approximately 3% of students achieved an Advanced Higher in Mathematics in 2011, almost exclusively from S6, or approximately 6% of those students in S6.

Mathematics in vocational education: Data on mathematics participation in vocational education in Scotland were not available. However, relatively few students leave school at S4 (age 16) for vocational education, although a larger proportion leave at the end of S5 (age 17) for vocational education. As a result, in our judgement, mathematics education largely takes place in general education, although there are likely to be some embedded mathematics options as well as some advanced mathematics options within vocational engineering courses.

Singapore

Some mathematics: An estimated 66% of students in post-secondary education, 61% of the age cohort, are enrolled in some mathematics courses. These participation estimates are essentially unchanged from our previous report.

Advanced mathematics: An estimated 39% of students in upper secondary education, 36% of the age cohort, are enrolled on advanced mathematics courses. This estimate has increased since our previous report partly because participation in advanced mathematics has risen in general education as a result of the reforms to A level and partly because we have been able to better estimate the advanced mathematics in vocational education. Although participation has risen at H1/H2 level as a result of the reforms, participation has fallen at H3. H3 is equivalent to the specialist option of Further Mathematics in England, although the content is more advanced.

Mathematics in vocational education: Vocational education accounts for a large proportion of upper secondary mathematics. 41% of the upper secondary, or education, employment and training, cohort takes basic mathematics within vocational education, 13% of whom take advanced mathematics.

US (Massachusetts)

Some mathematics: The estimates for the rates of participation in at least some mathematics (84% of the age cohort, or around 86% of the education, employment and training cohort) are unchanged from our previous report.

Advanced mathematics: The estimates for the rates of participation in advanced mathematics are unchanged from our previous report: 16% of students in the US participate in a calculus course. Massachusetts' performance on TIMSS is higher than the US generally, so participation in advanced mathematics is also likely to be higher than the US rate.

Mathematics in vocational education: Negligible. Almost all of upper secondary education is in general education.